QUALITY CONTROL AND MANAGEMENT

TREATMENT METHODS-LIQUID WASTE

Introduction

Water is a universal solvent but a cruel teacher, as the old saying goes, water in the pure form is a good solvent, but given an opportunity carries several factors responsible for disease in human being. Industrial effluents in general are known to contain several pathogens and hazardous chemicals used in the different processes. Another group of impurities that is typically of major significance in wastewater is the plant nutrients. Specifically, these are compounds of nitrogen, N, and phosphorus, P and pathogens in the wastewater is expected to be proportional to the concentration of fecal coliform bacteria. For example the coliform concentration in raw sanitary sewage is roughly one billion per liter.

Liquid waste is also characterized based on the Biological Oxygen Demand (BOD) and the Total amount of Suspended Solids (TSS). On the average, untreated domestic sanitary sewage has a BOD of about 200 mg/L and a TSS of about 240 mg/L. Industrial wastewater may have BOD and TSS values much higher than those for sanitary sewage; its composition is source dependent.

When considering the literature dealing with food wastewaters it is clear that the quantity and quality of wastewaters produced in the food industry vary considerably from process to process. In general, processing of food from raw materials requires large volumes of high-grade water which then generate large amounts of wastewater.

The liquid waste treatment generally involves reducing or removal of all the said contaminants. This episode deals with different types of liquid waste treatment with special reference to food industry. The following topics are highlighted

1. Sources of liquid waste in food industry
2. Composition of wastewater and selection of appropriate treatment methods
3. Wastewater generated from different food industries
4. Treatment methods: typical treatment sequence in a wastewater treatment plant
5. Treatment methods employed in different industries

1. Sources of liquid waste in food industry

Different sources contribute to the generation of wastewater in food processing industries, including meat processing, dairy products, seafood and fish processing, fruits and vegetable processing, starch and gluten products, confectionery, sugar processing, alcoholic/nonalcoholic beverages, and bean products.

Wastewaters released from these industries are turbid, with high concentrations of BOD, Fats, oils and grease, suspended solids (SS), and usually nitrogen and phosphorus. Hazardous chemical content is generally low. Other characteristics of food processing wastewater are

(a) Large seasonal variation,

(b) Large hourly variation and concentration in daytime,

(c) Factories are often of small scale,

(d) Sometimes unbalanced ratio of BOD:N: P that induces the bulking of sludge, and

(e) Colored effluent.

Before discharging wastewater back into the environment and the natural hydrologic cycle, it is necessary to provide some degree of treatment in order to protect public health and environmental quality. The basic purposes of liquid waste treatment are:

- To destroy pathogenic microorganisms
- To remove most suspended and
- To remove dissolved biodegradable organic materials

2. Composition of wastewater and selection of appropriate treatment methods

Waste water is mainly comprised of water (99.9%) together with relatively small concentrations of suspended and dissolved organic and inorganic solids. Among the organic substances present in sewage are carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their decomposition products, as well as various natural and synthetic organic chemicals from the process industries. Wastewater has characteristic changes in several of its parameters and few are described below.

pH

Similar to the temperature, the pH value has an impact on determining the suitable construction materials and the activity of microorganisms. To avoid damage to the sewage systems and the connected treatment plants, in Germany the pH value of the discharged effluent should be between 6.5 and 10. In treating wastewater, it is of importance which factors have influenced the pH. A low pH, for example, might result from organic or inorganic acids. Inorganic acids should be neutralized; organic acids should be biologically removed. For many microorganisms the ideal living conditions are at a relatively neutral pH value. Anaerobic wastewater treatment processes are especially sensitive to fluctuations in pH. It is important to keep in mind that organic acids can, at suitable organic loads, be degraded by biological plants without having to be neutralized. This, however, does not apply to mineral acids.

Obstructing Components

With regard to wastewater treatment, obstructing components are large inorganic particles, such as glass shards, plastic parts, sand, etc., which are biologically inert and need to be removed mechanically to avoid damage, clogging, or caking in the subsequent treatment process.

Total solids, suspended solids, filterable solids and settleable solids

The content of solid particles has a substantial effect on the amount of organic matter. One differentiates between total solids (TS), which consist of suspended solids (SS, all particles that do not pass through a membrane filter with a pore size of 0.45 μm), and filterable solids (FS). Settleable solids (unit: mL L^{-1}) are the solids that will settle to the bottom of a cone-shaped container; therefore, they do not include all of the suspended and floating solids.

Organic substances

Organic substances constitute the main pollutant fraction in most industrial plants. To prevent direct oxygen consumption in the waterways into which the effluent is discharged, organic substances need to be eliminated as far as possible. A variety of parameters can be used to determine the content of organic matter in a given wastewater sample: BOD, COD, etc. These sum parameters, however, do not include any indication of the kind of organic substances measured. The COD has developed into a major parameter, because the results of COD analysis are available much more quickly than those of BOD analysis. The use of cuvette tests gives an excellent cost–benefit ratio and requires less effort, space, and time to obtain results. The COD/BOD ratio is an important value in determining the biodegradability of the pollutants in a particular wastewater. If the ratio is <2, the load is considered easily biodegradable.

Nutrient Salts (Nitrogen, Phosphorus, Sulfur)

Nutrient salts are inorganic salts such as NH_4, PO_4, SO_4, which are considered vital for the growth of plants and microorganisms. Since nitrogen and phosphorous can cause massive growth of biomass and may therefore lead to eutrophication of water into which the effluent is discharged. In the European Union, nitrogen and phosphorous must be eliminated before wastewater is discharged into sensitive waterways.

To eliminate nitrogen and phosphorous biologically, sufficient organic pollutants must be present. Therefore, not only is the concentration of these substances in the industrial wastewater important, but also the ratio of their concentrations to the COD or BOD. Some kinds of industrial wastewater have such low nitrogen and/or phosphorous concentrations that nitrogen (in the form of urea) and/or phosphorous (as phosphoric acid) must be added to obtain the necessary minimum nutrient ratio for growth of the microorganisms needed for biodegradation.

Hazardous Substances

Hazardous substances are a generic term used for those substances or substance groups contained in wastewater which must be regarded as dangerous because they are toxic, long-lived, bioaccumulative, or have a carcinogenic, teratogenic, or mutagenic impact. In industrial wastewater, the following substances are of major importance:

- Absorbable organic halogen compounds (AOX)
- Chlorinated hydrocarbons and halogenated hydrocarbons
- Hydrocarbons (benzene, phenol, and other derivatives)
- Heavy metals, in particular mercury, cadmium, chromium, copper, nickel, and zinc
- Cyanides

In general, typical values of water consumption and pollutant contribution in beef, turkey, and broiler processing is as follows

Animal type	**Pollutant Load, kg/10000 animal**			**Water usage**
	BOD_5	**TSS**	**Fat and Grease**	**Liters/animal**
Beef	3044	3112	200	1325
Turkey	77	118	27	96
Broiler	22	26	3.6	22

These parameters along with the following factors determines the appropriate treatment methods to be employed, they are

- Production methods
- Water supply and water processing
- Technical condition and age of the production site
- Training and motivation of employees
- Use certain additives and cleaning agents, etc.
- Number of shifts, seasonal differences (campaign operation)
- Effluent requirements (direct or indirect discharge)
- Extent of production-integrated environmental protection means
- Number of wastewater treatment facilities

3. Waste water generated from different food industry

Water consumption is a major concern of the food industry. Apart from its frequent use as an ingredient, most of it ends up in the wastewater stream. It is important to adjust the Waste Water Treatment Plants (WWTP) operation according to the specific characteristics of the raw inlet stream and also to optimize the WWTP sludge treatment/disposal methods.

Wastewater pollution levels depend on the kind of raw material being processed, on the plant technology and the amount of wastewater generated is also an important factor as concentration of pollutants is inversely proportional to it. The general characteristics of wastewater generated from different food industry are as follows.

Meat and poultry

Characteristic properties of wastewater from slaughterhouses and poultry processing generally has a high organic load (up to 8000 mg/L BOD), is high in oils and grease, salt, nitrogen and phosphorus with SS at 800 mg/L or greater. It may also have a high temperature. The water may also contain pathogens like *Salmonella* and *Shigella* bacteria, parasite eggs and amoebic cysts. Pesticides may be also present, depending on the treatment of animals and their feed. Chloride levels may be very high from curing and pickling processes (77,000 mg/L). Besides that, fat and grease content is significantly increased by cooking activities in the plant.

Fish and shellfish

High organic concentration such as oils, proteins and SS is the important characteristic properties of wastewater from fish and shellfish processing installations. Phosphates, nitrates and chloride may be an issue as well. The properties of wastewater depend on the kind of fish being processed, with marked differences between white and fatty fish (e.g. because white fish are eviscerated at sea). Therefore, there is a wide variation in emission levels, e.g. COD may range from 2000 mg/L for white fish to 60,000 mg/L for oily fish species.

Fruit and vegetables

In the processing of fruit and vegetables, wastewater is generated in large quantities mainly by cleaning, but there may be other sources of pollution depending on the process. Typically, wastewater is high in SS, sugars and starches, often with additional pollutants like brines or acids. The requirements for aggressive chemicals are, however, low in comparison with other sectors, unless fats and oils are involved in the processing. In some cases, residual pesticides may appear in the wastewater stream, depending on the country of origin of the produce.

Vegetable oils and fats

Production of wastewater is again highly dependent on the source of oil as well as on the technology used for production. The amount of wastewater may reach levels up to 25 m^3 per tonne of product and it is typically high in COD, BOD and SS.

Dairy products

The dairy sector is a large producer of wastewater, which is caused by the amount of milk being processed, and the specific wastewater production ranges from 1:1 to 1:5 (volume of milk processed: volume of wastewater). Unlike other sectors, relatively reliable data on waste waster composition do exist. Besides high levels of BOD, milk, nitrogen, phosphorus and chloride are also present. Other properties of the wastewater, such as pH and temperature, are highly variable.

Sugar

The sugar production process results in a large volume of high strength wastewater, contaminated mainly by soil and sugar. Its COD levels may reach up to 20,000 mg/L.

4. Treatment methods

The variability of these wastewaters obviously affects the choice of sequence of processes for wastewater treatment. In order to design the correct treatment process, it is imperative that a truly representative sample of the stream effluent is obtained for characterisation. Not only may samples be required for the 24-hour effluent loads, but it is necessary that peak load concentrations, the duration of peak loads and the occurrence of variation throughout the day are determined.

It is necessary to remove the plant nutrients – nitrogen and phosphorus and also disinfect with chlorine to destroy most pathogens and help to prevent the transmission of communicable disease from wastewater. The removal of organics (BOD) and nutrients helps to protect the quality of aquatic ecosystems. Considering these in general, the waste water treatment methods are grouped into three general categories such as

- Primary treatment: Screening, grit removal, and sedimentation (settling)
- Secondary or biological treatment: biological processes and additional settling.
- Tertiary or advanced treatment: Microfiltration, ultrafiltration, reverse osmosis etc.,

A typical treatment sequence in a wastewater treatment plant consists of the stages listed below. Most industrial factories, however, have only a few of these operation stages, either because they do not have to cope with the respective pollutants in their wastewater or because they are exempted from particular treatment steps due to specific regulations, which occurs, e.g., with indirect dischargers.

1. Removal of obstructing substances (screens, grit chamber)
2. Solids removal (strainers, settling tank, flotation)
3. Storing equalization cooling
4. Neutralization or adjustment of the pH
5. Special treatment (detoxification, precipitation/flocculation, emulsion cracking, ion exchange)
6. Biological treatment or concentration increase (evaporation) or separation (membrane methods)

Primary treatment

These generally consist of a screening step (maybe double) and eventual grit removal. The screens used could be vibrating, rotary or static. Usually the screens used have from 10 mm to 1 mm openings. Material of small size can be removed by high speed circular vibratory polishing screens. Screening systems may be used in combination to maximize the efficiency of the process. Efficiencies of these systems are variable: rotary drum and disc show removal percentages up to 40–50% for suspended solids.

Flow equalization. Following the screening process and preceding the unit for suspended solids removal is a flow equalization step. Flow equalization is important in reducing hydraulic and organic loading in the biological process. Equalization facilities consist of a holding tank and pumping equipment designed to reduce the fluctuations of the waste streams. The equalizing tank will store excessive hydraulic flow and stabilize the flow rate to a uniform discharge rate over a 24-hour day.

pH adjustment. A pH adjustment is carried out after preliminary treatments in order to obtain a wastewater much more suitable for the biological processes following, generally in the neutral range.

Secondary treatment

Biological treatment processes (aerobic or anaerobic)

In several countries, most of the food processing plants deliver their wastewater to municipal systems after primary treatment, but in some cases the wastewaters may pass through a secondary biological (anaerobic or aerobic) treatment. In fact, to complete the treatment of the food processing wastewaters, the waste stream must be further processed by biological means. After adequate primary treatment, frequently used biological treatment systems include: anaerobic processes, extended aeration, aerated lagoons, trickling filters and land application. Recently, some new highly effective processes such as membrane bioreactors and jet loop reactors have come into operation.

Food processing wastewaters are particularly suitable for anaerobic treatment processes, firstly because of their high organic load and secondly because they rarely contain toxicants or inhibitory compounds. Indeed, excluding equipment cleaning operations, for which chemicals and disinfectants are normally used, all the sources of wastewater are related to the preparation and processing of animal- and vegetable-derived raw material and the wastewater characteristics are therefore mainly dependent on the nature of the organic matter processed. The upflow anaerobic sludge blanket (UASB) system has become the most widely applied reactor technology for high rate anaerobic treatment of industrial effluents.

The main reason for the success of the UASB is its relatively high treatment capacity (up to 10 kg COD/m^3 per day) compared with the other biological systems, which permits the employment of compact and economic wastewater treatment plants. In addition, anaerobic processes enable biogas production, with associated energy recovery, and are also characterized by low sludge production: typical yields are <0.1 kg volatile solids (VS)/kilogram of COD removed.

Activated sludge process treatment

In an activated sludge treatment system, an acclimatized, mixed, biological growth of microorganisms (activated sludge) is brought into contact with organic material in the wastewater in the presence of excess dissolved oxygen and nutrients (nitrogen and phosphorus). The microorganisms convert the soluble organic compounds to carbon dioxide and cellular material, i.e. new biomass. Oxygen is obtained from applied air which also maintains adequate mixing. The bioreactor effluent is settled to separate biological sludge and a portion of the sludge is recycled; the excess is sent for further treatment such as dewatering. Activated sludge systems utilized in the food processing industry are the extended aeration types: that is, they combine long aeration times with low applied organic loadings.

Aerated lagoon treatment

Aerated lagoons are generally used where there is not sufficient land available for seasonal retention or land application, and economics do not justify an anaerobic or activated sludge system. Efficient biological treatment can be achieved by the use of the aerated lagoon system. Air is applied to these ponds by fixed or floating mechanical aerators or by compressors through air diffusers located on the bottom of the pond between 2.5 and 5 m deep. Operating with 2–10 days retention time facilitates a reduction in BOD_5 of 55–90%.

Stabilisation pond treatment

A common practice for improving the effluent treated in the aerated lagoon is the use of stabilization/polishing pond system. This system depends on the action of aerobic bacteria on the soluble organics contained in the waste streams. The organic carbon is converted to carbon dioxide and bacterial cells. Algal growth is stimulated by incident sunlight which penetrates to a depth of 1–1.5 m. Photosynthesis results in the production of excess oxygen which is available to the aerobic bacteria; additional oxygen is provided by mass transfer at the air/water interface. The ponds are designed to provide a residence time of 2–20 days, with surface loadings of 5.5–22 g BOD_5/day per square meter.

Trickling filters

Trickling filters, utilizing plastic media in columns 4.5–6.0 m high, have been used in the treatment of high-strength fruit and vegetable wastewaters (3000–4000 mg/l BOD_5). High liquid recirculation rates and forced air circulation are used to achieve BOD_5 removals up to 90%. However, these processes tend to fail with the high organic load rates that are typical of some food processing wastewaters as, for example, in the cheese industry

Tertiary treatment

After the biological step, treated water can be further polished by means of specific tertiary treatments such as the use of membranes (microfiltration, ultrafiltration and reverse osmosis; Cheryan, 1998), or other chemical physical processes (activated carbon, precipitation, chelation) for the removal of specific pollutants and to further improve water characteristics.

Land disposal of wastewaters

The following methods are used for land application:

- irrigation,
- surface ponding,
- groundwater recharge by injection wells,
- subsurface percolation.

Irrigation is a treatment process that consists of a number of steps:

1. Aerobic bacterial degradation of the deposited suspended materials, evaporation of water and concentration of soluble salts.
2. Filtration of small particles through the soil cover, and biological degradation of entrapped organics in the soil by aerobic and anaerobic bacteria.
3. Adsorption of organics on soil particles and uptake of nitrogen and phosphorus by plants and soil microorganisms.

4. Uptake of liquid wastes and transpiration by plants.
5. Percolation of water to groundwater.

5. Treatment methods employed in different industries

Starch factory

Wastewater from starch factories has a high organic load and usually consists of easily degradable matter. The undissolved organic contents are mainly carbohydrates and proteins. The fat content is normally ~10%. Usually, this kind of wastewater does not contain any toxic substances. The substrate ratio COD:N: P is satisfactory; actually, there may even occur an excess of N and P, so that it is not necessary to add nutrient salts. The following processes are used for treatment of starch factory wastewater:

• Soil treatment

• Pond processing

• Small-scale technical processes (anaerobic, aerobic, evaporation)

Potato Processing Industry

Wastewater treatment systems often consist of the following sections:

- Grit chamber, screening system, settling tanks for purification of the flume and washing water recirculation
- Production-integrated screening systems and separators to recover organic solids that have been separated from the production wastewater and dewatered, to recycle valuable substances (e.g., cattle forage)
- Fat separators for wastewater containing fat, when deep-fat fryers are used in the production process
- Biological treatment for pretreatment and full treatment

Sugar factory

For the treatment of sugar factory wastewater, the following processes are common:

- Soil treatment
- Long-term batch processing
- Small-scale technical processes, usually consisting of anaerobic pretreatment and aerobic secondary treatment

Slaughterhouses

The primary wastewater and waste product sources are divided into three production areas:

- Truck washing and animal sheds (green line)
- Slaughter and cutting (red line)

- Stomach, intestine, and entrails cleaning (yellow line) – the latter, however, are often not done on the slaughterhouse grounds.

The following biological methods have until now been used successfully on an industrial scale:

- Large space biological methods (oxidation ponds, frequent formerly)
- Various activated sludge systems (single-stage, cascade, two-stage)
- Anaerobic biological methods

Conclusion

The wise decision in removing 0.1% of waste from 99.9% of water in the waste water has several benefits in terms of its reuse and environmental pollution. The appropriate methods need to be employed targeting the specific group of waste generally observed in an industry, so that treatment method is economically viable.